Propylene Oxide Producers Look for Ways To Counter Sluggish Market

■ ***Process improvements may lower production costs, but overcapacity threatens as new plants, producers enter business***

Susan J. Ainsworth, C&EN Houston

The U.S. propylene oxide market is experiencing some serious growing pains, and producers are actively taking precautions to ensure that their businesses remain healthy. The industry is seeing new technologies that may lower the cost of production, but at the same time, new producers and plants are contributing to the possibility of capacity vastly outstripping demand during the mid- to late-1990s.

Arco Chemical, with the newest plant, is probably studying these changes as intensely as anyone in the chemical industry. Sometime in the third quarter of this year, the company plans to start up a world-scale plant to produce both propylene oxide and styrene via the ethylbenzene peroxidation process at its Channelview, Tex., complex. The plant will have capacity to produce 500 million lb of propylene oxide and 1.13 billion lb of styrene annually.

For many years Arco Chemical and Dow Chemical have shared the propylene oxide market in the U.S. exclusively, each claiming about half of the business. The chemical is used primarily to make urethane polyols and propylene glycol. But last June, Texaco Chemical announced its intent to enter the market as a third producer, with a new plant to produce propylene oxide and methyl *tert*-butyl ether (MTBE) coproducts using the isobutane peroxidation process to go on stream in early 1994.

In addition, Dow Chemical is considering using lime instead of caustic soda in its chlorohydrin process for making propylene oxide. This likely would improve its cost position and free up a significant amount of its caustic for merchant sales. Another factor making the U.S. propylene oxide market less friendly is the recession, which has deflated demand for propylene oxide and some of its coproducts, such as styrene, and for end-use products such as flexible and rigid foams for furniture and auto seats.

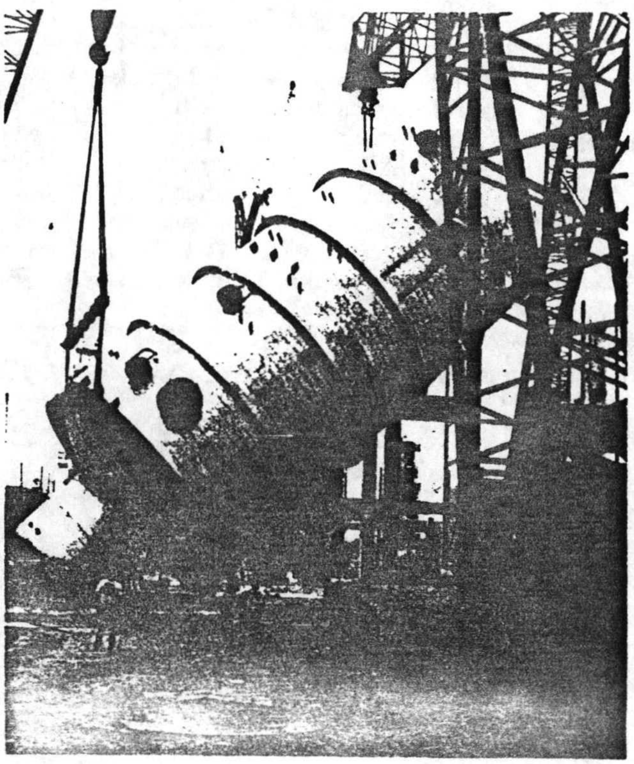
Although unfavorable market conditions and increased competition may have a negative effect on all U.S. propylene oxide producers, Arco Chemical and some industry observers believe that the company is best positioned to meet these challenges. That's because the company has the best cost position, a wealth of experience in operating propylene oxide plants, and equity partners to ease the burden of its coproduct styrene business.

It is tough for anyone to predict when propylene oxide demand will rebound. The market for propylene oxide is closely tied to the gross national product because it goes toward the production of "big-ticket consumer items such as automobiles and home furnishings," says Ronald L. Gist, a senior consultant at Pace Consultants in Houston.

Growth in propylene oxide may be buoyed by growth in demand for two key end uses—urethane polyols, which are used to make both flexible and rigid urethane foams used in automobiles, furniture, and bedding products; and propylene glycol, used in the production of unsaturated polyester resins for reinforced plastics, humectants for tobacco and food products, and for solvents used in the cosmetics industry.

"When the economy grows fairly robustly, propylene oxide grows a little faster than the economy," Gist says. On the other hand, "when there is a downturn, big-ticket items drop lower on a consumer's priority list, and propylene oxide grows slower than the GNP," he adds. Gist estimates that propylene oxide demand in the U.S. dropped less than 1% in 1991, but that it will grow about 1.5% between 1991 and 1992 and 2.6% per year in the mid-1990s.

Arco Chemical's forecast is brighter. From now through the mid-1990s, the company expects use of propylene oxide to grow 4% per year and that of styrene 3% per year in the U.S. Worldwide, the company predicts that propylene oxide



Crane lifts concentrator drum into place at Arco Chemical's Channelview, Tex., propylene oxide unit will grow 6% per year and styrene 4% per year through the middle of this decade.

Still, increases in consumption of propylene oxide probably won't compensate for the planned jump in production. Propylene oxide operating rates in the U.S. are now holding at about 85%, but that will likely drop to roughly 65 to 70% in 1994 when Texaco's capacity comes on stream, says Michael Horvath Jr., a petrochemical consultant with Petrocon Associates in Houston. "There is absolutely not enough room for another plant in this market right now."

Indeed, the market has changed significantly since Arco Chemical broke ground for its plant in June 1990. "The lead time it takes to start up a plant of this size is tremendous," says Joseph T. Lee, manager for projects and development at Arco Chemical. "Our first authorization for spending was back in 1988 when the market was robust, demand was strong, and everybody in the industry was operating near capacity."

When Arco Chemical decided to build the new plant, it considered two in-house peroxidation routes to propylene oxide. One starts with isobutane and gives a *tert*-butyl alcohol (TBA) coproduct, which can be converted to the gasoline additive MTBE. The other route, which the company eventually decided on, starts with ethylbenzene and produces coproducts propylene oxide and α-methylbenzyl alcohol, which can be dehydrated to styrene. Arco Chemical says it was not easy to decide between the two processes. Unfortunately, it is not technically feasible to operate a propylene oxide plant on a swing basis such that either of the two coproducts can be produced to satisfy demand fluctuations. "We thought both were relatively good investments," recalls Lee.

Arco Chemical chose the propylene oxide/styrene process because it would give it a better coproduct balance for styrene and MTBE in its worldwide market, says Lee. All of its European propylene oxide operations and two thirds of its U.S. propylene oxide operations are MTBE-based. The company did not want to be "weighted on that one technology" too heavily, he adds. On the other hand, "we think that styrene is a viable long-term business, and we are well positioned to operate within it."

Since those big decisions were made, "we've had to try to forecast where the industry and the overall economy were going to go." Arco Chemical, Lee adds, "anticipated a recovery some time in 1991 and it did not materialize."

Nevertheless, the company maintains that its investment in the new plant was necessary to position itself to meet its customers' needs into the future. "There's always going to be swings up and down [in demand], but we have a responsibility to our customers to guarantee that we can get materials to them," Lee says.

Horvath says that although lower operating rates will hurt all three propylene oxide producers, Arco Chemical will likely weather the storm best. Lee says, "We think the new Channelview unit will have the best [ratio of] capital per pound of product produced for this technology. It will probably be the most energy efficient plant of any of the propylene oxide–styrene units we have built. And because this is our newest plant, it is, environmentally, the tightest plant we have built."

Experience in building and operating propylene oxide plants is one factor that Arco Chemical has on its side. The company has been producing propylene oxide via the peroxidation process since the late 1960s, when it built its first such plant at Bayport, Tex. It has since fine-tuned its technology while building each of its nine propylene oxide plants around the world.

"There have been a lot of changes in just physical equipment alone," says Donald P. Mykytiuk, director of project management at Arco Chemical. Process improvements have evolved over time and with each new plant, and the older plants have been retrofitted to continually bring them up to date.

The construction strategy for the new plant involved off-site fabrication whenever possible to cut costs, says construction manager John T. Casey. For instance, Arco Chemical had two oxidizers fabricated and brought from Japan to the plant site, notes Mykytiuk. It also modularized the pipe racks for the plant and brought the units in by truck and barge.

With the expertise and technology improvements that Arco Chemical has honed over the years, "we now can get superior yields and efficient production out of smaller pieces of equipment," says Terry L. Stierman, technical superintendent at the new plant. "We've learned how to spend less capital but still get the best cost efficiency, energy efficiency, and yield efficiencies compared with any of Arco Chemical's previously built plants, all while maintaining high quality," he says.

Texaco also may have an edge in the marketplace by virtue of its peroxidation technology. When the company's propylene oxide and TBA facility in Port Neches, Tex., starts up in early 1994, it will enable Texaco to produce 400 million lb per year of propylene oxide and increase MTBE production from its current 4500 barrels per day to 19,500 bbl per day at Port Neches.

Now that Arco Chemical's basic patents on its peroxidation process have expired, some question whether Texaco's process is borrowed. A Texaco spokesman confirms that the company is employing a peroxidation process that yields propylene oxide and TBA coproducts, a process that in basic terms has long been used by Arco Chemical and other companies outside the U.S. But he adds that the process is "not identical to anyone else's process. It is our own proprietary process." Ralph S. Cunningham, Texaco Chemical president, says, "This project has additional importance because it uses technology that originated at Texaco Chemical's Austin [Texas] Research Laboratory. It is an example of developing proprietary technology to expand the company's product line."

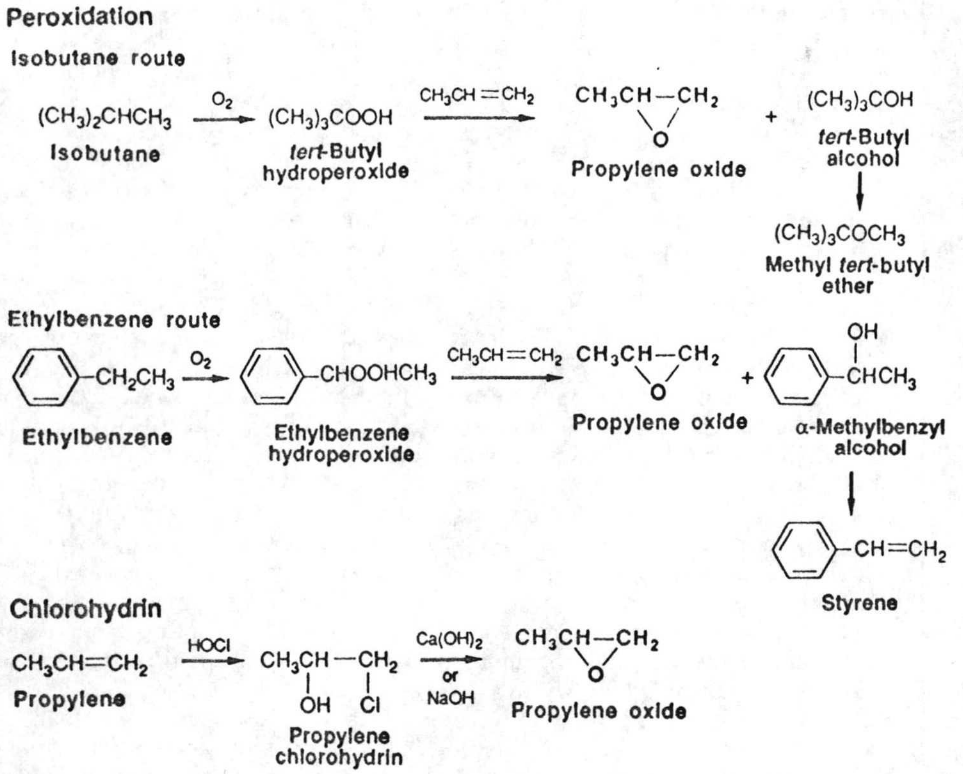
The expiration of basic patents on

Three firms will share U.S. market for propylene oxide

	Location	Annual capacity (millions of lb)	Basic process
Arco Chemical	Bayport, Tex.	1213	Peroxidation (isobutane)
	Channelview, Tex.	1100[a]	Peroxidation (ethylbenzene)
Dow Chemical	Freeport, Tex.	1100	Chlorohydrin
	Plaquemine, La.	450	Chlorohydrin
Texaco Chemical	Port Neches, Tex.	400[b]	Peroxidation (isobutane)

a Of this capacity, 500 million lb is slated to come on stream with a new unit in third-quarter 1992. b Slated to start up in first-quarter 1994.

Two major processes are used to produce propylene oxide



Source: SRI International

Arco Chemical's peroxidation process does not necessarily open the market up to all comers. Arco Chemical does not doubt that Texaco has done its own development work. The know-how necessary to operate a propylene oxide plant "goes way beyond what we put in a patent," says Lee. Taking technology from bench scale to commercial scale is complex, he adds, "and there are many safety and operating issues that you don't learn overnight. Anyone in an oxidation business can tell you that mixing hydrocarbons and oxygen is not without some inherent risk. With a number of years of operating experience, we have become more knowledgeable about how to operate. Besides, it is not a cheap technology to get into. I think that's one of the reasons we have held the position we have for a number of years."

Dow is likely to be hardest hit by the flood of new propylene oxide capacity, mainly because the processes used by Arco Chemical and the new Texaco plant provide significant cost advantages when the primary products, styrene and TBA, enjoy strong demand and pricing, says Petrocon's Horvath. "One major factor that may have influenced Texaco's decision to use the TBA process is the magnitude of the gasoline market, which will easily consume all of its TBA in making MTBE. So, propylene oxide may or may not be the driving force behind the new plants." By taking a cautious approach and not opting to add another propylene oxide plant, Dow will be in an awkward position in the near future, he says. "There's no room for another propylene oxide plant and there won't be for a long time unless Dow develops some breakthrough technology or replaces current chlorohydrin technology with a competitive peroxidation process."

Dow disagrees. David Naessens, product manager for polyurethane chemicals at Dow Plastics in Midland, Mich., says: "We don't see ourselves being at a great disadvantage. We obviously have done a lot of work looking at both of Arco Chemical's processes, and our conclusion is that after all of the depreciation of our plants, we are indeed competitive." In addition, he says, "unlike Arco Chemical and Texaco, we are not encumbered by coproducts. We run for propylene oxide economics alone."

Another plus on Dow's side is that the majority of the propylene oxide Dow makes is used internally. Texaco and Arco Chemical, he says, will have to rely more on merchant market sales. "Therefore, we will be running our plants at a higher rate of capacity." And he says Dow has not lost its chance to add capacity. Just last summer, Dow brought on a 200 million-lb-per-year expansion at Freeport and "we have another 400 million lb increment available to us there that we will bring on as the supply and demand balance dictates."

If Dow does modify its U.S. chlorohydrin process plants to use lime instead of caustic soda, the company will be more competitive with Arco Chemical on a cost basis, Horvath concedes. Lime, at roughly \$50 per ton, is cost-effective compared with caustic soda, which trades at about \$220 per ton. And the switch to lime would allow Dow to free up a significant amount of caustic soda to supply to merchant buyers without having to increase coproduct chlorine production.

Making the switch even more attractive, Dow is capable of producing its own lime. "Dow uses a lot of calcium carbonate and calcium chloride from sea shells in its magnesium process and it is very easy to convert calcium carbonate to calcium oxide, which is lime," Horvath adds. "In fact, Dow has drying furnaces at Freeport" that it can use to roast calcium carbonate limestone until all the carbon dioxide is driven off to make commercial calcium oxide, also known as caustic lime. "So it would be very easy for Dow to use that in a chlorohydrin process," Horvath conjectures. Naessens says that Dow has not yet decided to go with a lime process and that if it did, the company has many options for obtaining lime—and making its own is just one.

The switch is technically feasible; Dow already has propylene oxide facilities in Brazil and in Europe that use lime. What the company does have to ponder is the cost of converting its propylene oxide facilities at Freeport and Plaquemine, La., which would be considerable. The Freeport unit has propylene oxide capacity for about 1.10 billion lb per year and the Plaquemine facility is rated at 450 million lb per year. "The earliest we would make a decision to implement the lime process would be around 1995 or 1996, and it will depend on the economics of propylene oxide, caustic, lime, and Dow Chemical as a whole," Naessens adds.

Using lime "is a very interesting way for Dow to use its basic raw material position to help its overall profitability and make it more competitive with Arco Chemical," adds Horvath.

Arco Chemical, like the other producers of propylene oxide in the U.S., wants to be well positioned to take advantage of increased demand for propylene oxide when the economy finally does recover, which Gist expects will happen in 1992. Arco Chemical anticipates the recession will end and that consumption of propylene oxide will rebound. The cyclical forces that brought demand for these products down also will turn back up for companies that provide materials to the automotive and housing industries, the company believes.

Some of the propylene oxide from the new propylene oxide–styrene unit will be channeled toward supplying the urethane polyols business that Arco Chemical bought from Union Carbide in September 1991. The company was a major supplier to Carbide before the purchase. In addition, Arco Chemical says, it may tap the new plant to supply the 225 million-lb-per-year polyols plant at Channelview.

A part of the new capacity also may be used to supply growing outlets for propylene glycol. For example, some uses for ethylene glycol antifreeze have been converted to products based on propylene glycol, which has a lower toxicity profile. Ingestion of ethylene-glycol-based antifreeze is a commonly reported cause of poisoning in children and pets. Arco Chemical has very active programs both in the U.S. and in Europe to market propylene glycol to antifreeze formulators. In addition, it is touting propylene glycol's safety and environmental advantages over ethylene glycol in the deicers market. Aircraft deicing fluids have been based principally on this glycol, but now it has been listed as a hazardous air pollutant and the Clean Air Act has put pressure on airlines to find a substitute, says Lee. Arco Chemical has a propylene-glycol-based product for this end use, too. "We expect that both the aircraft deicing and antifreeze markets will give us significant new business and contribute to propylene oxide demand."

Arco Chemical is also involved in developing a number of other end uses for propylene oxide, including new derivative markets, says a spokesman. One example: the company's recent entry into the butanediol market. "We think that we are positioned to do that. We have the propylene oxide supply, we have the derivative capacity."

As for the coproduct styrene, "there will be factors that will affect how much styrene we produce." Principally, it will depend on demand for both propylene oxide and styrene. Arco Chemical can afford to be less concerned about that business. It has reduced its exposure to cyclicality in the styrene merchant market by signing on "equity partners" that have committed to a "significant portion of the styrene capacity of the new plant," says a spokesman. These unnamed partners will provide raw materials and pay their share of the plant operating costs, while not directly participating in the operation of the plant.

Arco Chemical believes, too, that the billion pounds of capacity for styrene that it is adding is only a small part of the world market for styrene, which totals 35 billion lb. "So in time [that capacity] will be absorbed by the demand in the marketplace," says Lee.

The export market is another viable outlet for Arco Chemical's propylene oxide and styrene. The company's worldwide production system allows it to take material from one location to another to meet demand until a new plant is built in that region. Given the cost involved in building one of these units, says Lee, "we don't want to make this investment all that often. So the flow of materials worldwide is something that we continually optimize."

Arco Chemical seems confident that its new plant, with its safety, environmental, and operating improvements, will be well equipped to meet the many market challenges it will face when it goes on stream later this year. Says Lee: "We have engineered and improved things incrementally over the past 25 years to the point where we have the most efficient system. There's no home run breakthrough in technology here, but I guess we've won the game by way of singles year after year [that were] accomplished by constantly improving our process." □

Top 50 Chemicals Production Stagnated Last Year

■ ***Although output was virtually unchanged from 1990, organics production moved up 3% while that of inorganics declined 1%***

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The economic slowdown finally caught up with chemical producers in 1991. Chemical export growth was not enough to counter the lag in most industrial markets or to help push U.S. chemical production to new heights in 1991, as it did in 1990.

According to C&EN's annual ranking of the 50 largest volume chemical products, total production in that group was virtually unchanged in 1991 from 1990. Production stagnated at the 633 billion-lb level registered the year before, which had been a good year. In 1990, production of the Top 50 rose 2% over 1989.

The Federal Reserve Board's data for 1991 also portray a commodity chemical slowdown. The Federal Reserve's seasonally adjusted indexes for basic and industrial chemical production increased less than 1%, respectively, between December 1990 and December 1991. And just as C&EN's Top 50 showed production gains in 1990 compared with 1989, Federal Reserve data indicate that between December 1989 and December 1990 seasonally adjusted basic and industrial chemical production increased (7% and 3%, respectively).

A year such as 1991 demonstrates just how much the cycle for commodity chemicals differs from that for other chemicals—for instance, specialty and pharmaceutical chemicals. These two categories are not included among C&EN's Top 50. However, the Federal Reserve's seasonally adjusted indexes show high-value pharmaceutical chemicals production rose almost 10% between December 1990 and December 1991. And plastic materials production, for instance, increased 5% during the same period.

Although the Top 50 in some ways reflects the general slowdown in business and the economy, commodity chemicals production is more a lagging indicator of economic conditions like

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1991. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, the production figures for earlier years that appear in the table on page 17 are different in some cases from those published in last year's Top 50 article. The final reports also can affect the rankings of chemicals. For the table on page 17, the 1990 ranking of 20 chemicals is different from last year's listing (C&EN, April 8, 1991, page 14).

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster includes basic inorganic chemicals, but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead burned) dolomite is excluded in lime production.

On the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included.

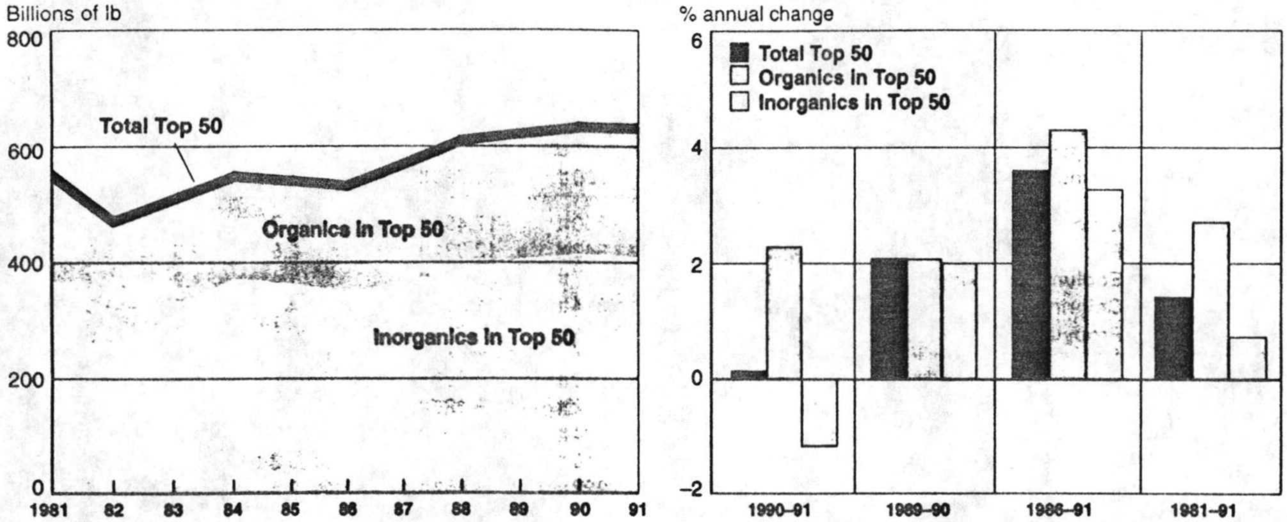
Production figures are published by the government in a variety of units—pounds, tons, cubic feet, gallons, metric tons, and most recently, kilograms and liters. Where the latter two units are used, they have been converted, where appropriate, into the common units that the government and industry have historically used as points of reference. To provide an accurate ranking and to make comparison of production volumes easier, C&EN lists production not only in common units, but also by weight in pounds.

Top 50 chemicals production totaled about 633 billion lb last year

Rank			Billions of lb		Common units[b]		Average annual change			
1991	1990[a]		1991	1990	1991	1990	1990–91	1989–90	1986–91	1981–91
1	1	Sulfuric acid	86.62	88.09	43,308 tt	44,044 tt	−1.7%	1.7%	3.8%	0.6%
2	2	Nitrogen	57.03	56.23	787 bcf	776 bcf	1.4	4.3	3.2	4.9
3	4	Ethylene	39.23	36.47	39,231 mp	36,473 mp	7.6	4.2	3.6	2.9
4	3	Oxygen	38.99	40.48	471 bcf	489 bcf	−3.7	8.2	3.4	0.9
5	6	Ammonia	34.04	33.59	17,020 tt	16,796 tt	1.3	2.0	4.0	−1.1
6	5	Lime[c]	33.60	34.90	16,800 tt	17,452 tt	−3.7	1.6	3.0	−1.1
7	7	Phosphoric acid	24.68	24.07	12,342 tt	12,034 tt	2.6	2.5	6.0	2.2
8	8	Sodium hydroxide	24.39	24.06	12,197 tt	12,030 tt	1.4	4.9	2.7	1.6
9	9	Chlorine	22.65	23.62	11,324 tt	11,810 tt	−4.1	3.5	1.6	0.5
10	10	Propylene	22.02	21.85	22,024 mp	21,849 mp	0.8	6.2	5.9	5.0
11	11	Sodium carbonate[d]	20.50	20.18	10,249 tt	10,090 tt	1.6	1.8	4.0	2.2
12	12	Urea[e]	16.14	16.24	8,072 tt	8,120 tt	−0.6	1.4	6.0	0
13	13	Nitric acid	15.05	16.00	7,524 tt	7,999 tt	−5.9	−4.2	2.8	−1.9
14	14	Ammonium nitrate[f]	14.62	14.16	7,310 tt	7,081 tt	3.2	−10.0	5.6	−1.9
15	15	Ethylene dichloride	13.92	13.85	13,922 mp	13,852 mp	0.5	3.5	1.5	3.4
16	16	Benzene	11.78	12.45	1,600 mg	1,690 mg	−5.3	4.2	3.3	2.0
17	17	Vinyl chloride	11.70	10.63	11,695 mp	10,626 mp	10.1	4.8	6.7	5.5
18	18	Carbon dioxide[g]	9.76	10.37	4,882 tt	5,186 tt	−5.9	−2.9	0	2.6
19	19	Methyl *tert*-butyl ether	9.60	8.89	9,600 mp	8,886 mp	8.0	8.0	23.3	28.9
20	20	Ethylbenzene	9.22	8.37	9,221 mp	8,370 mp	10.2	−9.4	0.4	1.7
21	22	Styrene	9.01	8.02	9,005 mp	8,017 mp	12.3	−3.9	2.7	3.0
22	21	Methanol	8.65	8.35	8,655 mp	8,346 mp	3.7	2.2	3.7	0.1
23	23	Terephthalic acid[h]	7.66	7.77	7,656 mp	7,775 mp	−1.5	−7.8	−0.1	2.1
24	25	Toluene[i]	6.80	6.21	937 mg	856 mg	9.5	6.9	8.9	1.0
25	24	Formaldehyde[j]	6.43	6.72	6,425 mp	6,721 mp	−4.4	14.0	3.0	1.2
26	26	Xylene	6.13	6.21	851 mg	862 mg	−1.3	−4.5	6.4	−0.3
27	27	Hydrochloric acid	5.60	6.03	2,799 tt	3,013 tt	−7.1	−7.8	3.2	0.8
28	29	*p*-Xylene	5.43	5.20	5,433 mp	5,202 mp	4.5	−2.7	1.5	1.8
29	28	Ethylene oxide	5.24	5.36	5,243 mp	5,356 mp	−2.1	6.4	−0.7	0.2
30	31	Ethylene glycol	4.93	5.07	4,930 mp	5,072 mp	−2.8	−7.1	0.7	1.8
31	30	Ammonium sulfate	4.46	5.08	2,230 tt	2,539 tt	−12.2	6.5	1.3	0.2
32	32	Cumene	4.28	4.31	4,284 mp	4,311 mp	−0.6	−2.6	2.7	2.6
33	33	Potash[k]	3.90	3.78	1,770 tmt	1,713 tmt	3.3	7.4	8.0	−2.0
34	34	Acetic acid	3.61	3.75	3,612 mp	3,751 mp	−3.7	13.9	5.8	1.6
35	36	Propylene oxide	3.60	3.20	3,600 mp	3,200 mp	12.5	0	7.7	6.9
36	35	Phenol[l]	3.49	3.54	3,486 mp	3,539 mp	−1.5	−7.0	2.3	3.1
37	37	Butadiene[m]	2.91	3.09	2,913 mp	3,089 mp	−5.7	−1.1	2.7	−0.2
38	38	Carbon black	2.72	2.87	2,723 mp	2,868 mp	−5.1	−1.5	1.0	0
39	39	Acrylonitrile	2.65	2.68	2,648 mp	2,677 mp	−1.1	13.2	3.9	2.9
39	40	Vinyl acetate	2.65	2.66	2,646 mp	2,659 mp	−0.5	4.2	9.1	3.2
41	42	Aluminum sulfate	2.36	2.45	1,180 tt	1,227 tt	−3.8	−1.3	−0.7	−0.9
42	41	Cyclohexane	2.31	2.46	2,309 mp	2,461 mp	−6.2	8.3	2.2	2.4
43	44	Titanium dioxide	2.19	2.15	1,093 tt	1,077 tt	1.5	−2.2	3.4	3.7
44	43	Acetone	2.13	2.33	2,130 mp	2,331 mp	−8.6	−7.7	1.9	−0.1
45	45	Sodium silicate	1.79	1.76	894 tt	880 tt	1.6	5.6	2.5	1.5
46	46	Adipic acid	1.56	1.62	1,560 mp	1,620 mp	−3.7	−1.2	0.5	1.2
47	47	Sodium sulfate[n]	1.54	1.57	768 tt	786 tt	−2.3	4.1	−0.2	−3.6
48	48	Isopropyl alcohol	1.30	1.38	1,297 mp	1,380 mp	−6.1	−6.4	−0.1	−2.5
49	50	Calcium chloride[o]	1.29	1.38	644 tt	690 tt	−6.7	−13.9	−3.8	−3.5
50	49	Caprolactam	1.28	1.38	1,283 mp	1,380 mp	−7.0	5.5	3.0	3.3
TOTAL ORGANICS			[illegible]	[illegible]			2.6%	2.1%	[illegible]	2.7%
[illegible]				[illegible]						
GRAND TOTAL				[illegible]						

a Revised. b tt = thousands of tons. bcf = billions of cubic feet. mp = millions of pounds. mg = millions of gallons. tmt = thousands of metric tons. c Except refractory dolomite. d Natural and synthetic. e 100% basis. f Original solution. g Liquid and solid only. h Includes both acid and ester without double counting. i All grades. j 37% by weight. k K_2O basis. l Synthetic only. m Rubber grade. n High and low purity. o 75% basis, solid and liquid.

Top 50 chemicals production unchanged in 1991



unemployment levels. According to the Department of Labor, seasonally adjusted unemployment levels rose during 1991. However, other government data indicate prospects for a recovery. For instance, housing starts began to swing upward in 1991 from their depressed level of 1990, according to the Department of Commerce.

Other measures of the economy also show evidence of new vigor. The Federal Reserve reports that seasonally adjusted auto and light truck production rose 12% between the fourth quarter of 1990 and the fourth quarter of 1991. (However, production of all transportation equipment declined 2% between 1990 and 1991.) Textile mill production increased 6%, and paper and paper products were up 2% during the same period, according to the Federal Reserve. All of these are big markets for chemicals.

Although these industries are all customers of Top 50 products, shipments still lag. Chemical and allied products shipments were down about 1% between December 1990 and December 1991, according to the Commerce Department. Meanwhile, chemical producers' inventories increased about 2%. So while the chemical industry has kept up production to meet an anticipated recovery in demand, the commodity chemicals business has not recovered enough to take advantage of those inventories.

A broad segment of industry economists believe chemical exports were a major factor in the growth of commodity chemicals production in 1990. U.S. exports of all chemicals rose 7% to 38.9 billion lb in 1990 from their 1989 level, according to the Commerce Department. But despite an estimate by the Chemical Manufacturers Association (CMA) that sets U.S. chemical exports at $44 billion for 1991, production recorded in 1991 for the Top 50 chemicals hardly changed from the previous year. If CMA's estimate proves sound, then exports probably kept 1991 from becoming a year in which commodity volumes declined significantly.

Among the largest volume chemicals produced in the U.S., sulfuric acid remains at the top with total production of 86.6 billion lb, down nearly 2% from 1990. The decline follows an approximate 2% rise from the previous year. For 1991, nitrogen continues to rank a distant number two, with production at 57 billion lb, up slightly more than 1% from 1990. Nitrogen's rate of growth slowed from 1990 when production rose a little more than 4% compared with 1989.

Of the Top 50, the 29 organic chemicals accounted for some 36% of total production, compared with almost 35% in 1990. The combined organics production increased nearly 3% in 1991 from the previous year, after a 2% rise in 1990. Over the five-year period 1986–91, combined production of organic chemicals among the Top 50 increased an average of a little over 4% a year. Historically, though, their output has grown at a slower pace. Between 1981 and 1991, combined output of organic chemicals among the Top 50 grew at a compound annual rate of almost 3% a year.

While organic chemical production continued to grow in 1991, inorganic chemical production declined compared with the previous year. Combined output of inorganics on the list declined a bit more than 1% from the previous year, following a 2% rise in 1990. Over the five-year period from 1986–91, combined production of inorganic chemicals grew at an average annual rate of 3% a year. Like theorganics group, inorganics production historically has grown at a slow pace: less than 1% between 1981 and 1991.

For organic chemicals, 11 of the 29 on the Top 50 list posted production increases. Organic chemical growth in 1991 was led by propylene oxide, production of which rose nearly 13% from 1990 to an estimated 3.6 billion lb. As a result, propylene oxide production moved to 35th place on the 1991 list from 36th place in 1990. Styrene production also grew at a double-digit pace, up 12% in 1991 to 9 billion lb. Styrene's strong growth moved it to 21st place on the Top 50 list from 22nd place in the previous year. Ethylbenzene production increased slightly more than 10% from 1990 to 9.2 billion lb, but its 1991 rank was the same as in 1990: It continues to hold 20th place. Vinyl chloride production also grew 10% in 1991 to 11.7 billion lb, and occupies the same position (17th) on the list in 1991 as in 1990.

None of the organic chemicals registered double-digit declines in production in 1991. However, the organic chemical registering the biggest drop last year was acetone, down 9% to 2.1 billion lb. The decrease moved it to 44th place from 43rd in 1990. Caprolactam output fell 7% to 1.3 billion lb in 1991, slipping the chemical from 49th place in 1990 to 50th in 1991.

For inorganic chemicals, 10 of the 21 on the Top 50 list posted production increases, led by fertilizer materials potash, ammonium nitrate, and phosphoric acid, each with approximately a 3% increase in 1991. Potash production rose to 3.9 billion lb. Its position on the Top 50 in 1991, however, at 33rd was unchanged from the previous year. Ammonium nitrate production rose to 14.6 billion lb and output of phosphoric acid increased to 24.7 billion lb. Neither advanced on the list—ammonium nitrate remained in 14th place, and phosphoric acid remained seventh.

Three inorganic chemicals had production increases of around 2%: sodium silicate, sodium carbonate, and titanium dioxide. Sodium silicate output increased to 1.8 billion lb and stayed in 45th place in 1991. Sodium carbonate production rose to 20.5 billion lb, giving it the same position, 11th, among the Top 50 in 1991 as it held in 1990. Titanium dioxide production rose to 2.2 billion lb, moving it up to 43rd place in 1991 from 44th the previous year.

Half of the inorganics on the Top 50 list recorded production declines in 1991 compared with 1990. Taking the biggest fall was ammonium sulfate, production of which dropped a little over 12% to 4.5 billion lb. The decline slipped it to 31st on the list, down from 30th in 1990. Two inorganics experienced about a 7% drop in production in 1991: hydrochloric acid and calcium chloride. Hydrochloric acid production was 5.6 billion lb in 1991, but its position on the list, 27th, remained the same as in 1990. Calcium chloride production dropped to 1.3 billion lb in 1991, but it moved up a notch in the listing to 49th place in 1991 from 50th in 1990—only because caprolactam registered a bigger decline. Carbon black and carbon dioxide both saw production declines of 6% in 1990. Output fell to 2.7 billion and 9.8 billion lb, respectively. □

Plastics, synthetic fibers output rise

Overall U.S. production of commercial polymers, including plastics, synthetic fibers, and synthetic rubber, edged up a little over 1% in 1991 compared with 1990. As a result, production reached a new high last year: 62.8 billion lb. However, growth was not so strong as in 1990 when polymer output rose 5% over the previous year and totaled 62 billion lb.

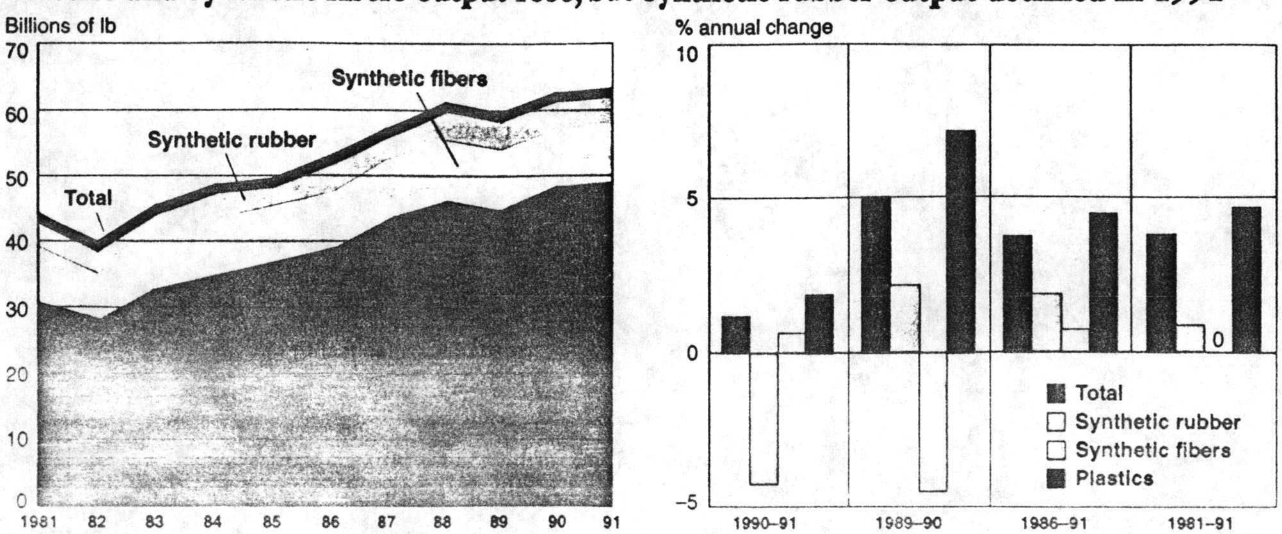
Plastics production, which accounts for more than three quarters of the polymer category's production total, led polymer growth in 1991 with a rise of nearly 2% to 49 billion lb. Synthetic fibers showed a production increase of less than 1% to almost 9 billion lb, and synthetic rubber output declined slightly more than 4% to just under 5 billion lb.

Production of thermoplastic resins grew a bit more than 3% to 43.3 billion lb in 1991 compared with 1990, following nearly 9% growth in 1990. Thermosetting resins production, however, dropped nearly 7% in 1991 to about 6 billion lb. This came after a decline of less than 1% in 1990.

Among the thermoplastics, high-density polyethylene production grew at an annual rate of almost 11% in 1991; it increased only 3% in 1990. Low-density polyethylene turned in the next best performance in 1991, with output up almost 4%, compared with a spectacular 15% rise in 1990. Production of polyvinyl chloride and copolymers rose slightly to just under 1% compared with a 7% increase in 1990. Polypropylene production hardly increased at all in 1991, compared with its 15% increase in 1990. For the second year in a row, polystyrene was the only thermoplastic to register a production decline, down slightly more than 1% in 1991 and nearly 2% in 1990.

In the thermosetting resins category, only unmodified epoxies recorded an increase in production, up more than 6% in 1991 following a 2% decline in 1990. Output of every other thermoset-

Plastics and synthetic fibers output rose, but synthetic rubber output declined in 1991



Total polymer production approached 63 billion lb in 1991

	Billions of lb		Common units				Average annual growth			
	1991	1990	1991	1990	1986	1981	1990–91	1989–90	1986–91	1981–91
PLASTICS (common units = millions of lb)										
Thermosetting resins[b]	**5.94**	**6.36**	**5,943**	**6,364**	**5,834**	**5,010**	**−6.6%**	**−0.6%**	**0.4%**	**1.7%**
Phenol and other tar acid resins	2.66	2.95	2,658	2,946	2,721	2,333	−9.8	2.3	−0.5	1.3
Urea resins	1.48	1.50	1,483	1,496	1,271	1,165	−0.9	1.4	3.1	2.4
Polyesters (unsaturated)	1.08	1.22	1,075	1,221	1,271	997	−12.0	−7.4	−3.3	0.8
Epoxies (unmodified)	0.53	0.50	531	499	398	336	6.4	−2.0	5.9	4.7
Melamine resins	0.20	0.20	196	202	173	179	−3.0	−9.0	2.5	0.9
Thermoplastic resins[b]	**43.26**	**41.91**	**43,255**	**41,912**	**33,569**	**25,671**	**3.2%**	**8.5%**	**5.2%**	**5.4%**
Low-density polyethylene	11.58	11.15	11,580	11,148	8,888	7,693	3.9	15.0	5.4	4.2
PVC and copolymers	9.17	9.10	9,168	9,096	7,256	5,707	0.8	7.3	4.8	4.9
High-density polyethylene	9.22	8.34	9,216	8,337	7,171	4,695	10.5	2.9	5.1	7.0
Polystyrene[a]	4.96	5.02	4,956	5,021	4,442	3,621	−1.3	−1.6	2.2	3.2
Polypropylene	8.34	8.31	8,335	8,310	5,812	3,955	0.3	14.8	7.5	7.7
TOTAL[b]	**49.20**	**48.28**	**49,198**	**48,276**	**39,403**	**30,681**	**1.9%**	**7.2%**	**4.5%**	**4.8%**
SYNTHETIC FIBERS (common units = millions of lb)										
Cellulosics[b]	**0.49**	**0.51**	**486**	**505**	**619**	**770**	**−3.8%**	**−12.9%**	**−4.7%**	**−4.5%**
Rayon[c]	0.27	0.30	273	299	404	509	−8.7	−17.6	−7.5	−6.0
Acetate[d]	0.21	0.21	213	206	215	261	3.4	−5.1	−0.2	−2.0
Noncellulosics[b]	**8.27**	**8.19**	**8,266**	**8,185**	**7,828**	**7,985**	**1.0%**	**−3.9%**	**1.1%**	**0.3%**
Polyester	3.41	3.20	3,410	3,195	3,305	4,176	6.7	−11.1	0.6	−2.0
Nylon[e]	2.54	2.66	2,537	2,662	2,514	2,333	−4.7	−2.8	0.2	0.8
Olefin[f]	1.87	1.82	1,865	1,822	1,393	785	2.4	11.2	6.0	9.0
Acrylic[g]	0.45	0.51	454	506	616	691	−10.3	−6.8	−5.9	−4.1
TOTAL[b]	**8.75**	**8.69**	**8,752**	**8,690**	**8,447**	**8,755**	**0.7%**	**−4.5%**	**0.7%**	**0 %**
SYNTHETIC RUBBER (common units = thousands of metric tons)										
Styrene-butadiene[h]	1.86	1.88	843	853	792	1,032	−1.2	−2.4	1.3	−2.0
Polybutadiene	0.92	0.91	415	412	336	342	0.7	0.2	4.3	2.0
Ethylene-propylene	0.51	0.59	232	266	230	178	−12.8	2.3	0.2	2.7
Nitrile	0.13	0.12	57	56	59	66	1.8	−18.8	−0.7	−1.5
Other[i]	1.47	1.60	668	725	596	404	−7.9	11.9	2.3	5.2
TOTAL[b]	**4.88**	**5.10**	**2,215**	**2,312**	**2,013**	**2,022**	**−4.2%**	**2.2%**	**1.9%**	**0.9%**
GRAND TOTAL	62.83	62.06					1.2%	5.0%	3.7%	3.7%

a No longer includes acrylonitrile-butadiene-styrene, or styrene acrylonitrile resins; historical data are restated. **b** Totals are for those products listed and may not add because of rounding. **c** Includes acetate tow beginning with 1985. **d** Includes diacetate and triacetate yarn, but does not include cigarette tow. Beginning with 1985, includes rayon yarn. **e** Excludes aramid after 1982. **f** Includes olefin film, olefin fiber, spun-bonded polypropylene, and vinyon. **g** Includes modacrylic. **h** Includes high-styrene latex. **i** Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. **Sources:** Society of the Plastics Industry, Fiber Economics Bureau, Rubber Manufacturers Association, International Institute of Synthetic Rubber Producers

ting resin—unsaturated polyesters, phenol and other tar acid resins, urea resins, and melamine resins—fell in 1991. They were down 12%, 10%, 1%, and 3%, respectively. In 1990, unsaturated polyester production declined 7%, phenol and other tar acid resins increased 2%, urea resins rose 1%, and melamine resins fell 9%.

Synthetic fibers output made a marginal recovery in 1991 from 1990, reaching 8.75 billion lb. Synthetic fibers registered an almost 1% production rise, shaking off the severe impact the recession had in 1990 when their production dropped 5%. Production of cellulosic fibers continued to slip in 1991, but the nearly 4% decline for the group was not so severe as the almost 13% drop the previous year. Noncellulosics production rose 1%, and polyester led the group with a nearly 7% production rise in 1991 following a 11% drop in 1990.

Production of synthetic rubber decreased 4% to less than 5 billion lb in 1991 compared with 1990, according to the International Institute of Synthetic Rubber Producers (IISRP), Houston. Synthetic rubber data from 1989 and prior years came from the Rubber Manufacturers Association (RMA), Washington, D.C. RMA discontinued its annual report of synthetic rubber production in 1990. An RMA spokesman says the government discontinued its report of synthetic rubber production, and without it RMA has no reliable source against which to check its own data. Only IISRP felt confident enough to release U.S. production data gleaned from its own membership survey.

According to IISRP data, nitrile rubber and polybutadiene were the only synthetic rubbers to show any growth last year, with nitrile rubber output up almost 2% and polybutadiene up less than 1%. All others registered declines in production, with output of ethylene-propylene falling the most, 13%, in 1991 compared with 1990. Production of a group of miscellaneous polymers, including neoprene, butyl, and polyisoprene declined nearly 8% in 1991.

Marc Reisch